Original article

DOI: 10.5114/areh.2022.118934

Advances in Rehabilitation, 2022, 36(3), 1–10

A – Research concept and design
B – Collection and/or assembly of data
C – Data analysis and interpretation
D – Writing the article
E – Critical revision of the article
F – Final approval of article

Received: 2022-04-06
Accepted: 2022-08-13
Published: 2022-08-19

Exercise therapy plus manual therapy improves acromiohumeral distance measured by real-time ultrasound in overhead athletes with shoulder impingement syndrome

Saurabh Sharma*[1,A-F], Shalini Sharma[1,2,A,C-E], RK Sharma[3,A,D-F], Abhinav Jain[4,A-B]

[1]Jamia Millia Islamia, A Central University, India
[2]Aged Care Home, Melbourne, Victoria, Australia
[3]Santosh University, Ghaziabad, Uttar Pradesh, India
[4]Jamia Hamdard University, India

***Correspondence:** Saurabh Sharma; Jamia Millia Islamia, A Central University, India; email: ssharma@jmi.ac.in

Abstract

Introduction: Shoulder impingement syndrome (SIS), characterized by decreased acromiohumeral distance (AHD), is a promising objective outcome measure with both clinical and research utility. The purpose of this study was to evaluate and compare the effectiveness of combining exercise therapy and manual therapy with motor control exercise on AHD in overhead athletes with SIS.

Material and methods: Ten overhead athletes with clinically diagnosed SIS were randomly assigned to two groups. The exercise therapy plus manual therapy (ET plus MT) group received the exercise therapy plus manual therapy regime, and the motor control exercises (MCE) group followed the motor control exercise protocol. Both groups underwent eight weeks of intervention, and AHD was evaluated at three levels of abduction (0°, 45°, 60°) with real-time ultrasound. The AHD evaluation was performed at baseline and at end of intervention (week 8).

Results: AHD improvement was noted at all three levels only in the ET plus MT group and the mean difference was found to be 2.62 ± 0.18 mm (0°), 3.28 ± 0.40 mm (45°) and 3.77 ± 0.30 mm (60°). Statistical analysis performed with two-way repeated measures ANOVA (3×2) revealed significant group effects for AHD (0°: $F(2,1.10) = 0.76$, $p < 0.001$; 45°: $F(2,0.98) = 0.80$, $p < 0.001$; 60°: $F(2,0.95) = 0.84$, $p < 0.001$). Time effect and interaction effects were also found to be significant.

Conclusions: ET plus MT appears to be a more effective rehabilitation tool than MCE since it improves AHD at 0°,45°, 60° in overhead athletes with SIS.

Keywords: rotator cuff impingement, manipulative therapy, resistance training, acromiohumeral interval

Introduction

Shoulder impingement syndrome (SIS) is a dysfunction where mechanical compression of the rotator cuff structures (muscles and bursa) occurs due to obliteration in the subacromial space [1,2]. SIS is characterised by a painful arc of motion during elevation and is the foremost cause of years with disability [3,4]. Of all reported shoulder injuries, SIS accounts for 27% of the injury burden in overhead athletes [3].

Acromiohumeral distance (AHD) is considered a good indicator of the subacromial space, and it is defined as the space between the superior humeral edge and the lateral most portion of the acromion [2]. In an anatomical position, a normal AHD measurement ranges from 8–13 mm with limited physiologic decrease, even on shoulder elevation [5]. Normal individuals can be differentiated from those with SIS using cut-off points identified by receiver operating characteristics (ROC) curves [6].

Several radiological methods exist today for the measurement of AHD, such as magnetic resonance imaging (MRI), X-ray, real-time ultrasound (RTUS) [6]. Of these, RTUS is a reliable, safe (no radiation emission), and inexpensive method for measuring AHD, and can therefore be used as an outcome measure for research purposes to assess the effect of different interventions [6]. RTUS has a higher level of agreement when measuring landmark distances as compared to structural diagnosis [7].

Physiotherapy interventions directed towards ameliorating the symptoms and impairments of SIS have long been used in clinical practice. Among these, active and passive exercise therapy and motor control have been reported to be beneficial in alleviating symptoms when used as independent approaches [8,9]. Exercise therapy works by activating the infero-medially directed muscle force couple, while the motor control exercises improve the scapulohumeral rhythm by facilitating neuromuscular coordination. Although these treatment approaches adopt differential pathways for mitigating impairments, both are based on decompression of the subacromial space or AHD [8,9].

Decompression of the subacromial space, which is synonymous with an increase in the AHD, is the primary objective of all physiotherapy interventions. AHD is dynamic in nature as it changes with shoulder movement in sports and during activities of daily living. This minimum physiological AHD is achieved by the sequential activation of the rotator cuff muscles and arthrokinematics of the shoulder girdle joints. Several studies have found a strong relationship between AHD and shoulder pathologies such as rotator cuff tears and SIS [2,6]. A reduction in AHD was found to be proportional to the magnitude of the SIS. An abnormal decrease in AHD can result in substantially elevated pain levels, as well as reduced shoulder strength and range of motion (ROM).

Previous clinical studies have evaluated the changes in AHD after rehabilitation intervention. One such study evaluate the relationship between functional status and variation in AHD during abduction before and after a four-week active rehabilitation program in patients suffering from SIS. Seven SIS patients underwent rehabilitation program comprising exercises (active, passive and stretching) of the scapular and shoulder muscles performed three times a week [10]. The study concluded a strong relationship between reduction in AHD and functional score before and after rehabilitation.

Akkaya et al. [11] subjected 18 SIS patients to weighted pendulum exercises (1.5 kg) and 16 to unweighted exercises (i.e. without a dumbbell) for four weeks, three sessions per day. The objective of the study was to investigate the effects of weighted and un-weighted pendulum exercises on ultrasonographic AHD. The exercises were repeated for each direction of shoulder motion in each session (ten minutes). Evaluation was performed at three angles: 0°, 30° and 60°. The study concluded that despite significant clinical improvement, no significant improvement in AHD was observed at any angle, as measured by RTUS [11]. Recent systematic reviews and quantitative analysis have also suggested that a scapular and rotator cuff strengthening exercise program should be included in the management of SIS. In addition, low to moderate quality evidence is present to support the use of manual therapy, either used alone or in combination with exercise approaches, in patients with SIS [12,13].

Loss of motor control (activation and coordination) of the scapulohumeral muscles is more closely associated with AHD during movement [14,15]. A strengthened muscle need not necessarily be recruited at the required time during shoulder movements. With this in mind, it is possible that the better neuromuscular control of movement observed after motor control intervention could improve impingement and increase AHD. Savoie et al. [16] recruited 45 participants: one group of 25 patients with SIS in one group and 20 asymptomatic controls in another. Both the groups were exposed to motor control exercise protocol for period of six weeks. The participants with SIS demonstrated an increase in AHD, and thus potentially a decrease in subacromial compression.

However, scant evidence exists regarding a comparison of combined exercise therapy and manual therapy with motor control exercise in overhead athletes with SIS. Therefore, the present study examines two evidence-backed rehabilitation modes *viz.*, exercise therapy and combined manual therapy with motor control exercise, in overhead athletes with SIS. Unlike previous studies, the present study also uses a novel outcome measure based on AHD rather than previously-used clinical measures such as pain or strength range of motion, and evaluates overhead athletes with SIS rather than a non-athletic population.

The aim of the study was to evaluate the effect of combined exercise therapy plus manual therapy (ET plus MT) compared to motor control exercises (MCE) on AHD at 0°, 45° and 60° in athletes with SIS. We hypothesized that both interventions would be able to optimize AHD; however, a greater improvement might be noticed in the ET plus MT group.

Materials and methods

Participants

This study was a single-blinded parallel group randomized pilot control trial with testing at baseline and then at eight weeks after completion of intervention in both groups. The outcome measure was AHD at 0°, 45° and 60° measured with help of RTUS.

Digital flyers were used for information dissemination and recruitment of overhead athletes from university teams according to predefined inclusion criteria: male, overhead athletes (cricket, basketball, volleyball, swimming), age 17–35 years, involved in sports training for at least six hours/week, pain levels on Visual Analogue Scale (VAS) of less than or equal to 7/10 (lower VAS limit: 3/10, upper VAS limit: 7/10), duration of shoulder symptoms for at least one month and positive demonstration of at least two out of five physical examination tests: Neer's sign, Hawkins sign, empty can test, abducted and externally rotated (ABER) position, relocation test [17−19]. The following were excluded: overhead athletes with neurological deficits, inflammatory arthritis, prior shoulder surgery or cortisone injection, and radicular pain in the upper extremity.

The assessment of the recruited athletes and intervention were carried out by qualified physiotherapists (minimum of two years clinical experience after qualifying physiotherapy postgraduate degree) with additional manual therapy certifications. Each athlete was given a unique identity number to maintain confidentiality. Overhead athletes diagnosed with SIS who met the inclusion criteria were enrolled into the study and randomly divided into two groups i.e., combined exercise therapy plus manual therapy (ET plus MT) or motor control exercises (MCE). These athletes underwent eight week-long intervention programs, and they were evaluated on outcome measures of AHD at baseline and post-intervention. Before beginning the intervention, demographic and anthropometric details were also recorded (body mass, height, and body mass index, years of playing experience, and type of sports). To reduce the chance of reading errors, three AHD readings were taken and averaged.

Sample size was calculated with G* Power software 3.192 version (Kiel, Germany). The *a* sample size of 10 athletes was calculated based on changes reported in AHD (change of 0.3 cm) in a previous study at an alpha level of 0.05 and power of 80% (1-beta) [23]. This research was approved by the institutional human ethics committee of the university and registered at clinical trial registry of India, vide number CTRI /2018/05/013892. As per the Helsinki declaration, written informed consent was obtained from all recruited overhead athletes.

Randomization and blinding

The athletes with SIS were randomly assigned to ET plus MT or MCE. Before the study began, an independent person created a random allocation list through free-to-use randomizer software that helped in deciding allocation to groups. Allocations were sealed and sequentially numbered and placed in opaque envelope. After the initial evaluation, confirmation for study enrolment and baseline measurement of AHD at three angles, the envelope was opened by the investigator. The investigator remained the same throughout the study and was blinded to the group allocation.

Procedure

ET plus MT group intervention protocol

Five overhead athletes in the ET plus MT group underwent this protocol consisting of graded progression of exercises (active and resisted) along with manual therapy. The total duration of the ET plus MT was eight weeks (three session/week) and each session lasted 45 minutes. In manual therapy, the thoracic spinal posteroanterior (PA) glides and glenohumeral (posterior) glides were performed over the hypomobile segments for a total of six sessions. For the PA thoracic glide, the athletes were positioned in the prone position and the therapist placed the hypothenar eminence (dominant hand) over the thoracic spinous process, and then interlocked it with a lumbrical grip of the other hand. Oscillatory grades of mobilization (grade I to IV) were used at the hypomobile segments where pain or resistance barrier was felt in joint play assessment (dosage: three rounds of oscillatory mobilization with each round of 90 second duration). Grade I mobilization was defined as a small amplitude oscillatory movement at the beginning of the available range of movement (ROM), grade II as a large amplitude oscillatory movement within the available ROM, grade III as a large amplitude oscillatory movement that enters the hypomobile/barrier zone, grade IV as small amplitude movement stretching deep into hypomobile/barrier zone. The glenohumeral posterior glide was executed with the athlete in the supine position and the affected shoulder slightly off the plinth. While cradle holding the arm of the athlete with one hand, the therapist placed the palm of the opposite hand on the front of the anterior surface of the shoulder for performing the oscillatory mobilization (dosage: 3 rounds of oscillatory mobilization with each of 90 second duration) [20].

This group also underwent graded progression of the exercise, based on exercise hardening and dividing the exercise protocol into two phases of four weeks each. Phase 1 consisted of free active exercise in multiplanar physiological motion within the limits of pain (dosage:10 reps/day) along with a stretching exercise of the posterior capsule of the shoulder (active cross-body horizontal adduction with further stretch enhanced by an opposite hand gripping around the elbow joint – dosage: 5 times × 30 s hold). The strengthening exercises were performed with elastic resistance bands, with progression from yellow to red to green to blue. The exercise range comprised shoulder internal rotation (IR) and external rotation (ER) in the neutral position, shoulder extension, and scapular protraction/retraction in the supine position (dosage: 10 reps × 2 sets, progression of elastic band resistance done on weekly basis).

The total duration of phase 1 (strengthening exercises) was two weeks [21,22]. The phase 2 strengthening program lasted for another two weeks (weeks 3 and 4). The exercises were graded in difficulty level by increasing the angle of shoulder elevation. The shoulder ER and IR were performed in 45°–90° abducted position, flexion to 90°, push-up plus exercise and scapular exercises for middle and lower trapezius muscles (Week 3 dosage: 10 reps × 2 sets; Week 4 dosage: 10 reps × 3sets; progression of elastic band resistance increased on a weekly basis as per fatigue level). Phase 3 lasted from Week 5 until Week 8; in this phase, the athletes performed the phase 2 exercises along with the addition of chair-press push-ups and protraction planks (dosage: 2–3 sets × 10 reps; progression of elastic band resistance increased on a weekly basis as per fatigue level) [21,22]. A summary of the intervention is presented in Table 1.

MCE intervention protocol

The athletes in the MCE group were asked to perform six planar exercises for the upper quadrant daily for eight weeks. This group did not undergo any

Tab. 1. Detailed description of the intervention in the ET plus MT group (repetition and sets)

	Inception to Week 4	Week 5 to 8
Phase 1 ROM exercises Stretching exercises (7 days a week)	Daily: 1 set ×10 reps Daily: 30 sec hold × 5 times	Daily: 1 set ×10 reps Daily: 30 sec hold × 5 times
Manual therapy (Grade I to IV oscillatory technique) Thoracic PA glides in prone position Posterior & inferior GH glides in supine position	6 sessions in first 4 weeks	6 sessions in second 4 weeks
Strengthening exercises Shoulder IR and ER (neutral position) Shoulder extension Scapular retraction and protraction(supine) Scapular retraction with tuck in chin	1st week: 2 sets × 10 reps 2nd week: 3 sets ×10 reps (Graduate to red to green to blue resistance bands)	n/a
Phase 2 Shoulder elevation and flexion (up to 90°) and resisted extension Shoulder ER and IR [45°–90°] Quadruped push-up plus "camel" Scapular "T" and "Y" exercise	3rd week: 2 sets ×10 reps 4th week: 3 sets × 10 reps (Graduate from yellow to red colour resistance bands)	2–3 sets × 10 reps (Graduate from green to blue resistance bands)
Phase 3 (in addition to phase 2 exercises) Chair press protraction-plank	n/a	Week 5 to 8: 2–3 sets × 10 reps

ER – external rotation, GH – glenohumeral joint, IR – internal rotation, n/a – not applicable, PA – posteroanterior, reps – repetitions, ROM – range of motion, sec – second progression of the exercises or increase in resistance during the entire eight weeks of treatment. The intervention was directed towards the facilitation of neuromuscular coordination and adaptation. The exercises comprised shoulder abduction in the frontal plane (athlete were asked to perform it at their own pace without shoulder hike), shoulder retraction (pulling the two blades of the scapula together without shoulder lifting and holding the contraction for 15 seconds, followed by relaxation), shoulder shrugging (lifting both the shoulder blades upwards towards the ceiling and holding the contraction for 15 seconds, followed by relaxation), neck retraction (bringing the tragus of the ear in line with the acromion process for a duration of 15 seconds followed by relaxation), upper trapezius stretching exercises (the athlete was comfortably positioned on a chair with one hand on the affected side, gripping the lateral side of the chair, and the opposite hand pulling the head towards the opposite shoulder in the coronal plane, dosage: three times × 30 s hold, twice daily). The athlete also performed pectoralis major stretching exercise: briefly, the athlete adopted a lunge standing position in corner of the room, with both shoulders in ABER position on the wall : abducted and externally rotated to 90°, and elbow also flexed to 90°. The stretch was achieved by increasing the lunging by further flexion of the front limb, dosage: three times x 30 s hold, twice daily [9].

Outcome measure

With the help of a radiologist, RTUS was performed for the recruited overhead athletes with SIS. For the present study, a BT15 system ultrasound device (GE machine P8) with a 9–12 MHz transducer head was used, placed in the coronal plane for the measurement of AHD. With the athlete comfortably sitting on the chair the AHD measurement was performed in three different positions of shoulder abduction (0°, 45°, 60°). There are basically two rationales behind using these angles. Firstly, the AHD is most reduced between 60° and 120° of shoulder abduction, and AHD documentation beyond these angles is difficult because of acoustic shadows [7]. Secondly, the athletes with SIS reported significant pain levels, therefore holding the position beyond these angles might have further aggravated the pain level and affected the interventional compliance.

The AHD for the 0° position was measured with the arm by the side of the body, and the forearm in the mid-prone position with the hand clenched in a thumbs-up position. For the 45° to 60° measurements, the arm was pre-positioned into the desired abduction with help of a strap-belt (further confirmed by goniometer) (Fig. 1). The length alterable strap-belt was fixed at two ends, i.e. at the chair handle and elbow region, as it aided in maintaining the desired shoulder angle. The athletes were required to perform elbow flexion of 90° with thumbs upward in the forearm mid-prone position [10].

Statistical analysis

Statistical analysis of the measured AHD was performed using SPSS software version 21.0 (SPSS Inc. Chicago, Illinois). The demographic and anthropometric characteristics were taken at baseline. The AHD data were expressed as mean ± standard deviation and the units of measurement were in millimetres (mm). The normality of the data was assessed with the Shapiro-Wilk test. For continuous data, the unpaired t-test was used to find the difference between age, height, weight BMI, years of playing, and AHD on the affected side at baseline, while a chi-square test was used for categorical data. The paired samples t-test (within-group) was used to compare mean ± standard deviation (SD) of the AHD values between baseline and eight weeks post-intervention. Levene's test was used to assess the homogeneity of variance, and Mauchly's test of sphericity for the assumption of sphericity ($p > 0.05$ referenced as a violation of sphericity). To elucidate the effect of each intervention on outcome measure (AHD: 0°; AHD: 45°; AHD: 60°), two-way repeated measure ANOVA (analysis of variance) (3 × 2) was carried out with time (baseline and post-intervention; Week 8) as within-subject factors, and groups (ET plus MT and MCE) as between-subject factors.

Fig. 1. RTUS images of AHD measured at 45° shoulder abduction

Group effects, time effects and interaction effects of group × time were also statistically analysed. Partial eta squared represented the effect size, categorized as small (0.01), moderate (0.06), and large (0.14) [24]. The minimum clinically important difference (MCID) was also calculated using a distribution-based method. The MCID corresponds to $0.5 \times SD_{pooled}$ where $SD_{pooled} = \sqrt{\Sigma(n_i-1) \times SD_i^2 / \Sigma(n_i-1)}$ where n_i was the number of participants per trial arm and SD_i was the standard deviation value per trial arm [25]. The significance level was set at $p < 0.05$ for the study.

Results

The present study recruited 10 overhead athletes diagnosed with SIS; each of the participants were randomly assigned to the ET plus MT (n = 5) and MCE (n = 5) groups. The study reported no dropouts for present trials, as indicated in the CONSORT flow diagram (Fig. 2).

The results showed no significant difference in demographic or outcome measure characteristics (AHD) at baseline, suggesting high homogeneity among the two groups (Tab. 2).

The unpaired t-test exhibited significant between-group difference post intervention in AHD in favour of the ET plus MT group at 0° ($p < 0.05$), at 45°($p < 0.05$) and at 60° ($p < 0.05$) (Tab. 3). The paired t-test revealed significant within-group improvement in the ET plus MT group for the AHD at all degrees. No significant change was observed in the MCE group (Tab. 3) (Fig. 3).

Variances were assumed to be equal, as Levene's test for homogeneity and Mauchly's test of sphericity were yielded non-significant results ($p > 0.05$). Two-way repeated measures (2x2) ANOVA found significant main effects for group on AHD 0° ($F(3,1.10) = 0.76$, $p < 0.001$), AHD 45° ($F(3,0.98) = 0.80$, $p < 0.001$), AHD 60° ($F(3,0.95) = 0.84$, $p < 0.001$). Main effects for time were also found to be significant for AHD 0° ($F(3,1.95) = 0.25$, $p < 0.001$), AHD 45° ($F(3,1.30) = 0.32$, $p < 0.001$), AHD 60° ($F(3,1.03) = 0.35$, $p < 0.001$). The analysis revealed significant interaction effects AHD 0° ($F(3,1.23) = 0.80$, $p < 0.001$), AHD 45° ($F(3,1.05) = 0.67$, $p < 0.001$), AHD 60° ($F(3,1.09) = 0.75$, $p < 0.001$). The largest effect size, denoted by partial eta squared, was noted in group effects in the following descending order: AHD 60°, AHD 45°, and AHD 0°. The MCID of AHD for the ET plus MT trial arm was calculated to be 0.09 mm (0°), 0.20 mm (45°), and 0.15 mm (60°). The MCID for the MCE trial arm was further calculated to be 0.45 mm, 0.26 mm and 0.22 mm for the three angles.

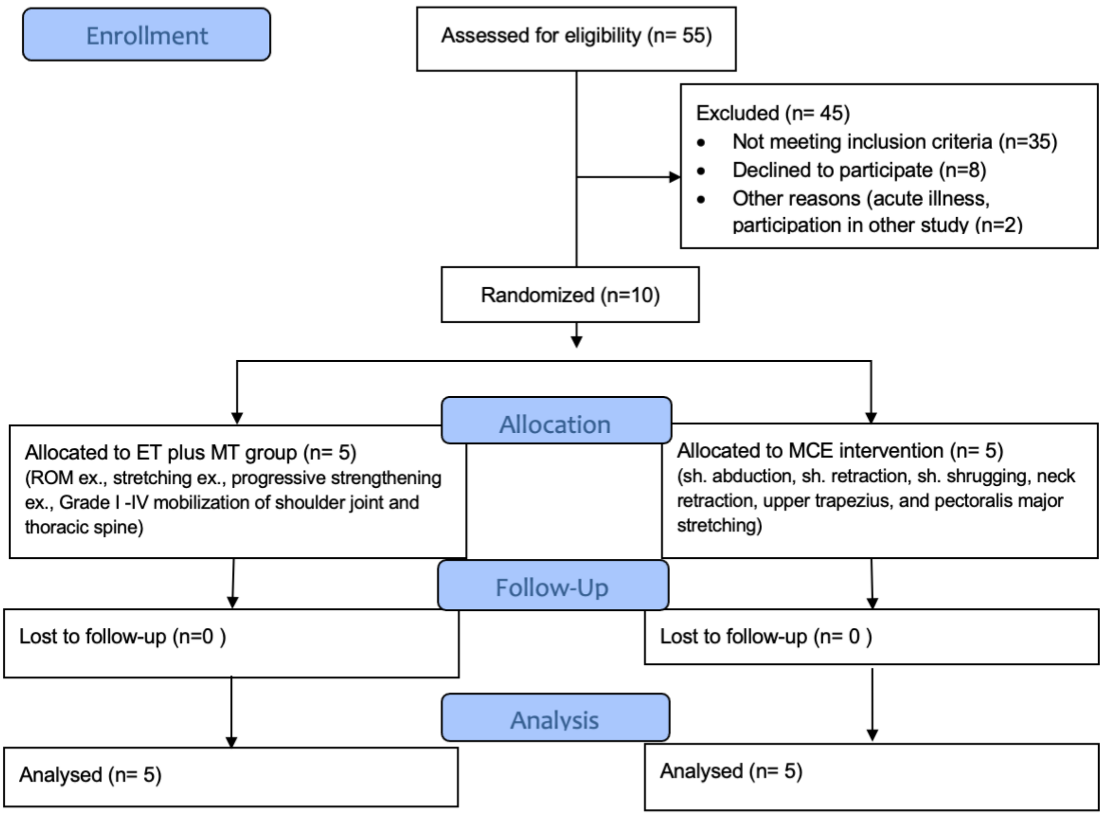

Fig. 2. CONSORT Flow Diagram

Tab. 2. Demographic data of overhead athletes with SIS

Variables	ET plus MT group (n = 5)	MCE Group (n = 5)	t-test	p-value
Age (years)	21.01 ± 1.04	21.22 ± 1.56	1.23	0.56
Weight (kg)	68.56 ± 1.45	67.92 ± 1.50	0.97	0.21
Height (cm)	172.89 ± 6.90	173.10 ± 5.56	0.91	0.92
BMI (kg/m^2)	22.87 ± 1.32	22.56 ± 1.01	1.45	0.34
Duration of symptoms (weeks)	12.45 ± 3.78	12.01 ± 0.98	1.01	0.46
Years of playing	4.44 ± 1.10	4.11 ± 1.78	0.75	0.18
Sports Discipline	3C/5V/2BB	5C/1V/4BB	0.55	0.15
Affected side	3R/2L	4R/1L	n/a	n/a

Data is in the form of Mean ± SD, BMI – body mass index, C/V/BB – cricket, volleyball, basketball, ET plus MT group – exercise therapy plus manual therapy group, L – left, MCE Group – motor control exercise group, n/a – not applicable, R – right, SD – standard deviation

Tab. 3. Comparison of means and mean difference of AHD at two time-points

Abduction Angle	Group	AHD (baseline)	AHD (Post-intervention)	Mean difference (Within group)	Between-group p-value
0°	ET plus MT	7.74 ± 0.43	10.36 ± 0.11	2.62 ± 0.18*	2.35 <0.05*
	MCE	7.94 ± 0.92	8.01 ± 0.90	0.07 ± 0.91	
45°	ET plus MT	6.84 ± 0.68	10.12 ± 0.10	3.28 ± 0.40*	2.66 <0.05*
	MCE	7.36 ± 0.78	7.46 ± 0.83	0.10 ± 0.52	
60°	ET plus MT	6.29 ± 0.26	10.06 ± 0.32	3.77 ± 0.30*	3.68 <0.05*
	MCE	6.48 ± 0.27	6.38 ± 0.83	0.10 ± 0.45	

Data is in the form of Mean ± SD, AHD – acromiohumeral distance, ET plus MT group – exercise therapy plus manual therapy group, MCE Group – motor control exercise group, SD – standard deviation, * – significant $p < 0.05$.

Discussion

The purpose of this research was to compare ET plus MT and MCE interventions in terms of improvement in AHD at various shoulder angles in overhead athletes with SIS. The outcome measure of AHD was measured at two time-points: baseline and week 8 after the beginning of the intervention. Our findings indicate that the ET plus MT group exhibited a significantly greater improvement in AHD in athletes with SIS compared to the MCE group at all three angles.

The repeated measures ANOVA also indicated significant group, time, and interaction effects for the AHD outcome measure. Our findings are in line with previous research suggesting that an impingement syndrome group demonstrated greater improvement in AHD levels compared to healthy participants. Although the intervention plan was on similar lines as our study and it included stretching exercises, manual therapy, resistance and closed kinetic chain exercises, the results demonstrated a greater mean change after the intervention compared to the present study (0.64 mm vs 3.77 mm) [23]. This could have been due to the shorter duration of intervention, i.e. four weeks as compared to eight weeks in this study.

In another study, scapular setting exercises (SSE) performed on 28 SIS patients also exhibited similar significant improvement of AHD, as indicated by ultrasonography. Each patient underwent AHD measurement with and without SSE. During SSE, the therapist initially helped the patient orient the scapula in upward rotation and posterior tilt, and this position was maintained by the patient for seven seconds. Towards the end of the hold time, the AHD measurement was performed by the evaluator at 0° and 60° of elevation. The between-group mean difference in the study was reported to be 1.16 at 0° (vs 2.35) and 0.96 at 60° (vs 3.68). A larger margin of difference was obtained in our study; this could

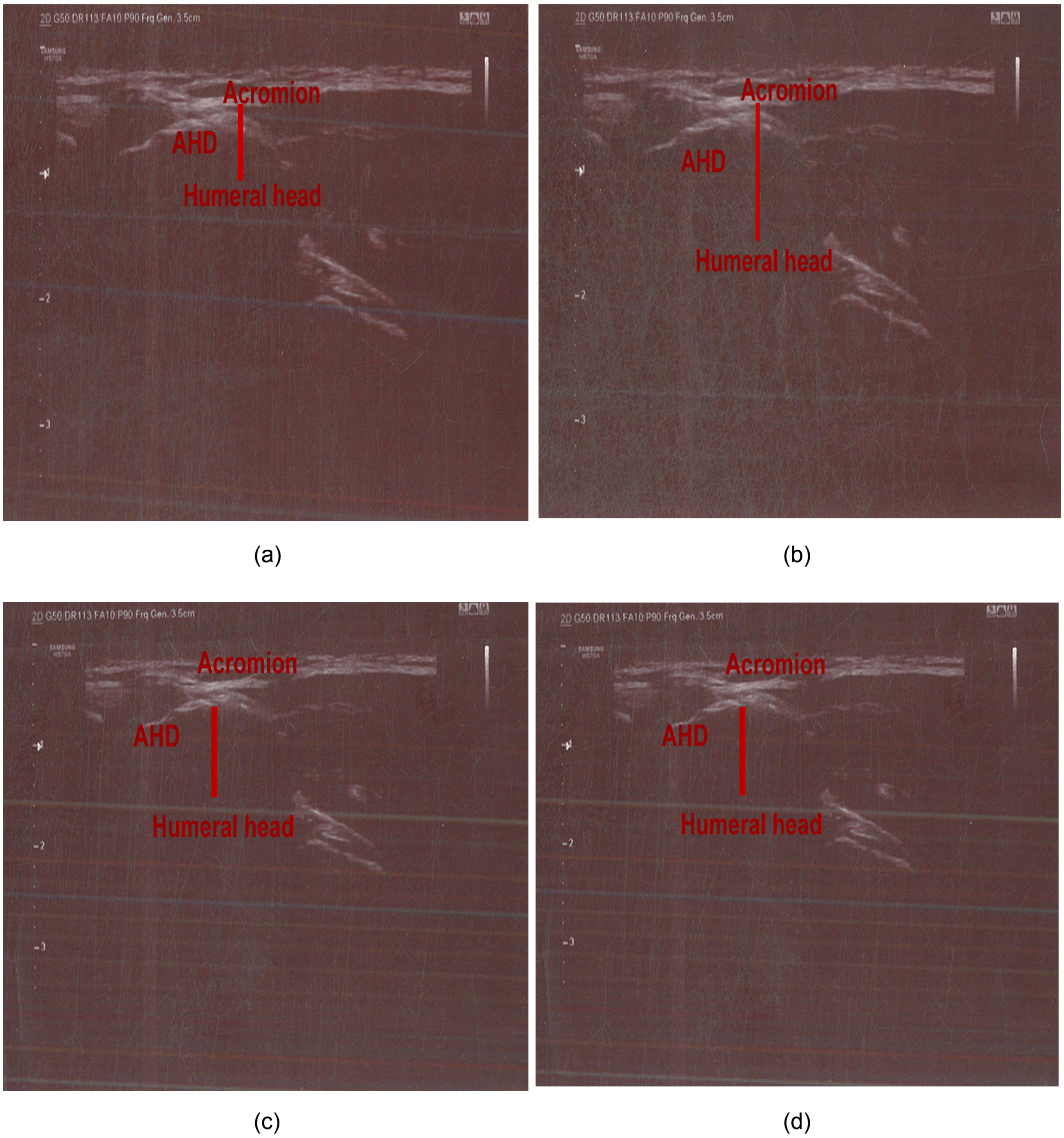

Fig. 3. RTUS images of AHD measured at 45° shoulder abduction; (a) ET plus MT group: Baseline AHD; (b) ET plus MT group: Post intervention AHD; (c) MCE group: Baseline AHD; (d) MCE group: Post intervention AHD

be attributed to it being a cross-sectional study, with no particular intervention being provided to patients [26].

In contrast, other studies have compared weighted (1.5 kg) and unweighted free exercises for four weeks in SIS patients. The participants performed exercises in each direction of shoulder motion. Despite noting within-group improvement in AHD, no between-group differences were concluded. No improvement was observed in the unweighted exercise group; this may be due to the shorter duration of the intervention and the use of non-progressive low threshold exercises [11].

Three rationales can be elaborated for the results obtained in our study. Firstly, the deltoid muscle (three fibres) is known to be the prime mover for elevation movements, i.e. abduction and flexion, of the shoulder joint. The elevation motion is usually a powerful motion due to the contribution of three deltoid fibres, but this benefit comes with the disadvantage of a superior humeral glide, which mechanically decreases the subacromial space or AHD and precipitates SIS symptoms. The strengthening exercise in the ET plus MT group directed towards the infraspinatus, teres minor and subscapularis contributed to the development of a stronger inferomedial force couple to offset the superior translatory pull of deltoid muscle, thus facilitating an increase in AHD [27,28].

Secondly, the stretching component in the ET plus MT group also helped in the release of the tight posterior shoulder capsule known to be present in athletes with SIS. The adoption of a thoracic slouched posture and rounded shoulder (excessive protraction) is a reflexive action for pain reduction [29]. It also mechanically affects the scapular kinematics (decreases scapular upward rotation, external rotation, posterior tilting) and shortens the posterior capsule, with a subsequent decrease in AHD [30]. The stretching exercises might have contributed to AHD improvement by optimizing the posterior capsule length.

Thirdly, the MCE group was not able to exert beneficial effects on AHD as our protocol had primarily neuromuscular exercise components. Although it is important to include neuromuscular coordination in the management of SIS, the intervention did not sufficiently alleviate the strength and hypomobility impairments in SIS athletes and improve the AHD compared to the control group; this was probably due to a our study having a shorter intervention that previous studies [31].

As statistical significance is not always clinically beneficial, MCID is considered an important factor in medical research. Therefore this was calculated in the present study. In previous studies, the mean increase in AHD was found to be 0.28 mm elevation for 0° and 0.34mm for 60° [11,16]. Both these values are much lower than the MCID value of 0.7mm and therefore they can be counted under measurement errors [32]. In our study, improvements larger than 0.7mm MCID were observed, and these changes can be explained by the fact we submitted the SIS athletes to an evidence-based rehabilitation program.

Our findings have important implications for clinical practice. For athletes with SIS, adding manual therapy to exercise therapy to increase AHD is more effective than MCE alone. Secondly, AHD can be used by clinicians as a barometer to measure improvement in addition to the other routine clinical measures.

This study has many strengths. It is one of the few studies that have evaluated the change in AHD in athletes with SIS, and none of the athletes in either group reported any adverse effects due to the intervention. It also describes the first comparison of two promising protocols, ET plus MT and MCE, intended to improve AHD. However, it has a couple of limitations. Firstly, it does not include any long-term follow-up intended to check the temporal stability of the findings. Secondly, the findings are specific to athletes with SIS and they should not be generalised to other shoulder pathologies such as SLAP injury, instability or rotator cuff tears. Thirdly, the sample size was small, and double blinding was not performed. Future studies should assess the AHD in different angles of elevation and correlate it with the ability to return to sports in different shoulder pathologies.

Conclusion

The use of combined ET plus MT offered significant benefits over MCE alone in improving the AHD at 0°, 45°, and 60° of shoulder abduction. This intervention is an effective conservative method for optimizing AHD and should be recommended to overhead athletes with SIS.

Acknowledgements
The authors would like to thank the Vice-Chancellor of the University for providing the necessary support for the research.

Funding
This research received no external funding.

Conflicts of Interest
The authors have no conflict of interest to declare.

References

1. Garving C, Jakob S, Bauer I, Nadjar R, Brunner UH. Impingement syndrome of the shoulder. Dtsch Arztebl Int. 2017; 114(45): 765-76.
2. Xu M, Li Z, Zhou Y, Ji B, Tian S, Chen G. Correlation between acromiohumeral distance and the severity of supraspinatus tendon tear by ultrasound imaging in a Chinese population. BMC Musculoskelet Disord. 2020; 21(1): 106.
3. Bolia I K, Collon K, Bogdanov J, Lan R, Petrigliano FA. Management options for shoulder impingement syndrome in athletes: insights and future directions. Open Access J Sports Med. 2021; 12: 43-53.
4. Saupe, N, Pfirrmann CW, Schmid MR, Jost B, Werner CM, Zanetti M. Association between rotator cuff abnormalities and reduced acromiohumeral distance. AJR Am J Roentgenol. 2006; 187(2): 376-82.
5. Scheyerer MJ, Brunner FE, Gerber C. The acromiohumeral distance and the subacromial clearance are correlated to the glenoid version. Orthop Traumatol-Sur. 2016; 102(3): 305-9.
6. Sharma S, Hussain M, Jain A, Moiz JA. Diagnostic accuracy and reliability of sonographic evaluation in overhead athletes with shoulder impingement syndrome. JCDR. 2018; 12(8): 17-21.
7. Schmidt WA, Schmidt H, Schicke B, Gromnica-Ihle E. Standard reference values for musculoskeletal ultrasonography. Ann Rheum Dis. 2004; 63: 988-94.
8. Land H, Gordon S, Watt K. Effect of manual physiotherapy in homogeneous individuals with subacromial shoulder impingement: A randomized controlled trial. Physiother Res Int. 2019; 24(2): e1768.

9. Holmgren T, Hallgren HB, Öberg B, Adolfsson, L, Johansson K. Effect of specific exercise strategy on need for surgery in patients with subacromial impingement syndrome: randomised controlled study. BMJ. 2012; 344: e787.
10. Desmeules F, Minville L, Riederer B, Côté CH, Frémont P. Acromio-humeral distance variation measured by ultrasonography and its association with the outcome of rehabilitation for shoulder impingement syndrome. Clin J Sport Med. 2004; 14(4): 197-205.
11. Akkaya N, Akkaya S, Gungor HR, Yaşar G, Atalay NS, Sahin F. Effects of weighted and un-weighted pendulum exercises on ultrasonographic acromiohumeral distance in patients with subacromial impingement syndrome. J Back Musculoskelet Rehabil. 2017; 30(2): 221-8.
12. Desmeules F, Boudreault, J, Dionne C, Frémont P, Lowry V, MacDermid JC, et al. Efficacy of exercise therapy in workers with rotator cuff tendinopathy: a systematic review. J Occup Health. 2016; 58(5): 389-403.
13. Dong W, Goost H, Lin XB, Burger C, Paul C, Wang ZL, et al. Treatments for shoulder impingement syndrome: a PRISMA systematic review and network meta-analysis. Medicine (Baltimore). 2015; 94(10): e510.
14. Boudreau N, Gaudreault N, Roy JS, Bédard S, Balg F. The addition of glenohumeral adductor coactivation to a rotator cuff exercise program for rotator cuff tendinopathy: a single-blind randomized controlled trial. J Orthop Sports Phys Ther. 2019; 49(3): 126-35.
15. Charry FB, Martínez MJL, Rozo L, Jurgensen F, Guerrero-Henriquez, J. In vivo effects of two shoulder girdle motor control exercises on acromiohumeral and coracohumeral distances in healthy men. J Man Manip Ther. 2021; 29(6): 367-75.
16. Savoie A, Mercier C, Desmeules F, Frémont P, Roy JS. Effects of a movement training-oriented rehabilitation program on symptoms, functional limitations and acromiohumeral distance in individuals with subacromial pain syndrome. Man Ther. 2015; 20(5): 703-8.
17. Cools AM, Witvrouw EE, Declercq GA, Danneels LA, Cambier DC. Scapular muscle recruitment patterns: trapezius muscle latency with and without impingement symptoms. Am J Sports Med. 2003; 31(4): 542-9.
18. De Mey K, Danneels L, Cagnie B, Cools AM. Scapular muscle rehabilitation exercises in overhead athletes with impingement symptoms: effect of a 6-week training program on muscle recruitment and functional outcome. Am J Sports Med. 2012; 40(8): 1906-15.
19. Cotter EJ, Hannon CP, Christian D, Frank RM, Bach Jr BR. Comprehensive examination of the athlete's shoulder. Sports Health. 2018; 10(4): 366-75.
20. Tate AR, Mcclure PW, Young IA, Salvatori R, Michener LA. Comprehensive impairment-based exercise, and manual therapy intervention for patients with subacromial impingement syndrome: a case series. J Orthop Sports Phys Ther. 2010; 40(8): 474-93.
21. Kuhn JE. Exercise in the treatment of rotator cuff impingement: a systematic review and a synthesized evidence-based rehabilitation protocol. J Shoulder Elbow Surg. 2009; 18(1): 138-60.
22. Kachingwe AF, Phillips B, Sletten E, Plunkett SW. Comparison of manual therapy techniques with therapeutic exercise in the treatment of shoulder impingement: a randomized controlled pilot clinical trial. J Man Manip Ther. 2008; 16(4): 238-47.
23. Zaky LA, Sabet Nazm, Mohamed MM, Mosad, AE. Effect of Exercise Program on Acromiohumeral Distance in Subacromial Impingement Syndrome. J Med Sci Clin Res. 2016; 4(5): 10568-74.
24. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. Front Psychol. 2013; 4: 863.
25. Mouelhi Y, Jouve E, Castelli C, Gentile S. How is the minimal clinically important difference established in health-related quality of life instruments? Review of anchors and methods. Health Qual Life Outcomes. 2020; 18: 136.
26. Kim SY, Weon JH, Jung, DY, Oh JS. Effect of the scapula-setting exercise on acromio-humeral distance and scapula muscle activity in patients with subacromial impingement syndrome. Phys Ther Sport. 2019; 37: 99-104.
27. Reinold MM, Escamilla R, Wilk KE. Current concepts in the scientific and clinical rationale behind exercises for glenohumeral and scapulothoracic musculature. J Orthop Sports Phys Ther. 2009; 39(2): 105-17.
28. Ackland DC, Pandey MG. Lines of action and stabilizing potential of the shoulder musculature. J Anat. 2009; 215(2): 184-97.
29. Do Youn Lee CWN, Sung YB, Kim K, Lee HY. Changes in rounded shoulder posture and forward head posture according to exercise methods. J Phys Ther Sci. 2017; 29(10): 1824-7.
30. Kalra N, Seitz AL, Boardman III ND, Michener LA. Effect of posture on acromiohumeral distance with arm elevation in subjects with and without rotator cuff disease using ultrasonography. J Orthop Sports Phys Ther. 2010; 40(10): 633-40.
31. Worsley P, Warner M, Mottram S, Gadola S, Veeger HEJ, Hermens H, et al. Motor control retraining exercises for shoulder impingement: effects on function, muscle activation, and biomechanics in young adults. J Shoulder Elbow Surg. 2013; 22(4): e11-e19.
32. McCreesh KM, Crotty JM, Lewis JS. Acromiohumeral distance measurement in rotator cuff tendinopathy: is there a reliable, clinically applicable method? A systematic review. Br J Sports Med. 2015; 49(5): 298-305.